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WESTERN AND NORTHERN CANADA ACID DEPOSITION LRTAP ACTIVITIES

ANNUAL REPORT 1987

A report on monitoring and research studies related to acid rain and long-range transport of atmospheric pollutants in Western and Northern Canada

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ANNUAL REPORT 1987

A report on monitoring and research studies related to acid rain and long-range transport of atmospheric pollutants in Western and Northern Canada

prepared by the
Technical Committee for the
Long-Range Transport of Atmospheric
Pollutants in Western and Northern Canada

April 1988

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MAP OF WESTERN CANADA

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1. INTRODUCTION

History

Before 1980, very little was known about the acid rain issue in western and northern Canada. Precipitation chemistry data from a sparce regional network of federal stations in these regions suggested that acidic deposition was not a serious problem; but, the environmental impacts occurring in eastern Canada and United States provided a strong incentive to develop a better base of scientific information.

On September 4, 1980, deputy ministers and senior officials from Environment Canada and the environment ministries of British Columbia, Alberta, Saskatchewan, and Manitoba, met in Edmonton to review the available information on acid rain and long-range transport of air pollutants (LRTAP) in western Canada. They concluded that acid rain was not a serious problem in the west. But, because of an increase in industrial activity in western Canada and in the western United States, they agreed that surveillance of LRTAP and acid rain is justified. They established a Consultative Committee of deputy ministers and a Technical Committee of senior officials from the four western provinces and Environment Canada to coordinate monitoring, research and other activities related to acid rain and LRTAP.

In December 1982, the Committees, which by then included representatives from the Northwest Territories, launched a research program to identify current conditions in western Canada and provide the information necessary to develop management strategies.

The acidic deposition management strategy adopted by the governments is to protect the sensitive ecosystems. This strategy has four basic elements:

1. Determining the sensitivity of the western and northern Canadian environment to acidic deposition.
2. Establishing deposition standards or target loading values for elements causing acidic deposition that are suitable for the sensitivity of this environment. (Target loading is defined as the maximum tolerable level of the chemicals that cause acidic deposition consistent with the long-term protection of the highly and moderately sensitive areas of the environment.)
3. Monitoring to ensure compliance with the targets.
4. Establishing emission management plans as necessary.

Current Status

The first six years of coordinated research have satisfied several of the management strategy elements (see Table 1). These accomplishments are discussed below.

Table 1 Summary of Western and Northern Canada LRTAP Program 1982 - 1988

Goal	Accomplishments	Remaining Tasks
Determine Sensitivity	– soils and geology sensitivity mapping (1988) – surface waters sensitivity mapping (1988)	– vegetation sensitivity mapping (1990/91) – fill in gaps in mapping – soils and surface waters – field studies sensitive areas
Establish Target Loadings	– interim target loading report (1988)	– task group recommend interim loadings – identify research needed to refine loadings
Monitor for Compliance	– provincial wet deposition networks – CANSAP – CAPMON expanded to Manitoba Saskatchewan, and Alberta	– expand CAPMON to BC, NWT and YT – determine role of dust – measure dry deposition – include provincial, territorial data in NATCHEM
Emission Management Strategy	– emissions inventory (1986) – apply AES – LRTAP model to Western Canada (1984) – mesoscale modelling task group (1985) – acquire and test statistical and MESOPUFF II models – oxidant modelling (Vancouver) – control technology options (1987) for acid gas emissions	– validate models

Sensitivity Maps

Sensitivity maps to acid deposition have been prepared for soils, geology, and lakes in western and northern Canada. Significantly, this mapping activity has identified major areas that are highly sensitive to acidic deposition effects. The sensitivity maps are contained in two reports which have been prepared to provide an overview of the sensitivity of the various regions in western and northern Canada. There is, however, no evidence of acidification.

Target Loadings

In the application of the target loading concept, it is recognized that it is the total deposition (wet plus dry) that really matters. Since the dry deposition (in gaseous or particulate form) is extremely difficult to measure, the target loading is normally expressed in terms of wet deposition (in the form of rain, snow, or fog, for example).

The federal and provincial governments of Canada have accepted the concept of a "target loading" based on sulphates to control the deposition of acidic pollutants in surface waters. A value of 20 kilograms per hectare per year (kg/ha/yr) of wet sulphate deposition was developed for protecting lakes in eastern Canada which have moderate sensitivity to acidic deposition. This target loading is site specific to eastern North America and thus is not directly applicable to western Canadian environmental conditions. Therefore, suitable target loadings for western and northern Canada had to be developed.

This process began with a contract to the National Research Council of Canada in 1985. The report **Interim Target Loadings for Acid Deposition in Western Canada: A Synthesis in Existing Information** was released in February 1988. This report documents the scientific rationale for interim target loadings in western Canada. A task group has been formed to develop the interim target loading values. Further research will be required to refine these values and ensure they are scientifically validated.

Deposition Monitoring

Precipitation chemistry is now monitored at 62 locations across western and northern Canada. Wet sulphate deposition at most locations is less than 10 kg/ha/yr (Figure 1), but is greater than 20 kg/ha/yr at one station, Vancouver. Approximately 15% of the monitoring stations experience average wet sulphate deposition greater than 10 kg/ha/yr.

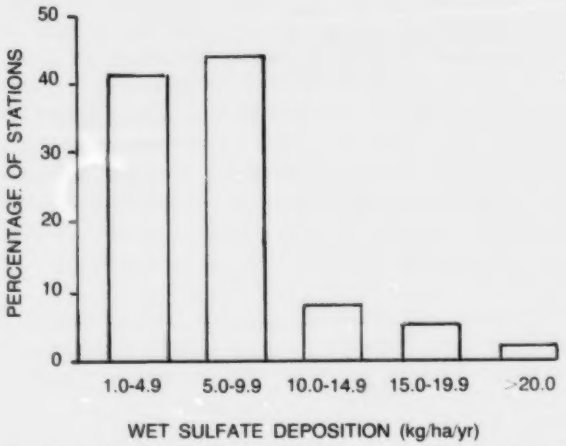

Figure 1. Annual wet sulfate deposition at 39 stations in western and northern Canada.

The Canadian Air and Precipitation Monitoring Network (CAPMON) is a regional scale air and precipitation monitoring network which has 22 stations located across Canada. The western Canada portion of the network consists of two stations in Manitoba and one each in Saskatchewan and Alberta. A search for suitable sites in British Columbia, Northwest Territories and the Yukon is underway. Progress has also been made with the integration of provincial precipitation chemistry data into a national database (NATCHEM).

Dry deposition has not been measured on a systematic basis due to the difficulty of measurement. However, some calculations indicate that it may range from 5-22 kg/ha/yr of sulphate at locations in Alberta, with an average for the province of 16 kg/ha/yr.

One of the current difficulties in interpreting sulphate deposition data from monitoring stations in dry climates is to account properly for the role of sulphate in windblown dust in the total deposition. In coastal areas some of the deposited sulphate comes from sea salt, but by using sodium chloride concentrations this neutralized sulphate can be calculated and subtracted. Unfortunately, no similar mechanism exists to correct for sulphate from windblown dust.

A task group is currently evaluating the role that dust plays in precipitation chemistry in western and northern Canada.

Emissions Management

Total sulphur dioxide emissions in the four western provinces decreased from 1938 kilotonnes (kt) in 1972 to 1156 kt in 1982 (Table 2), a reduction

of approximately 40%. Manitoba currently has an emission ceiling of 738 kt/yr; however, by 1994 the ceiling will be lowered to 550 kt as part of the sulphur dioxide emission reduction program in eastern Canada. Other local control programs may have to be undertaken in this region if monitoring indicates that observed deposition rates exceed the interim target loading. In addition, new industrial sources of sulphur dioxide would be evaluated to determine if the additional impact on the environment is within acceptable limits.

Transport and deposition models will be essential to this management strategy, just as dispersion models are vital to evaluating air quality impacts for common pollutants. Attempts to use Environment Canada's long-range transport model which was developed and validated for eastern North America, have indicated that it is not well suited for western and northern Canada. Rather, medium range or mesoscale models suitable for shorter distances with fewer contributing sources are more appropriate.

In 1985 a task group was formed to evaluate mesoscale models which could be applied over western Canada. In the report **A Review of Mesoscale Modelling for Application To Western Canada,** several models were recommended for implementation and validation.

The validation of these models, which requires a multi-year program is currently underway. In addition, sulphur dioxide and nitrogen dioxide atmospheric emissions inventory methods have been developed (Western Canada LRTAP Air Emission Inventory Working Group 1986) to ensure uniformity in determining emissions in western and northern Canada.

Future Activities

The participating agencies will have basic information available on three of the four elements of an acidic deposition management strategy by the end of the current program in 1991. The sensitivity mapping, deposition target loadings and current deposition monitoring data will make it possible to activate the management strategy. Full implementation will require further refinements of our current knowledge.

At the present time, studies of the effects of acidic deposition on animal and human health are not considered to be necessary in western and northern Canada, with the exception of Alberta, where these aspects are being addressed by the Alberta Government/Industry Acid Deposition Research Program. From the national perspective, the acid rain issue is quite different in the eastern and western regions of Canada. Western Canada does not experience high levels of wet sulphate deposition over widespread areas, hence both the science and the control methods must focus on a more localized scale. This difference is reflected in the issues which the western program has carried forward: a uniform protocol for precipitation sampling, regional background deposition levels, mesoscale (medium range) deposition models, and deposition standards for highly sensitive ecosystems. Clearly, the issue in western and northern Canada is environmental protection rather than environmental recovery or reclamation.

Table 2 Western Canada Sulphur Dioxide Trends (103 t/yr)

	YEAR			
Province	**1972**	**1976**	**1978**	**1982**
British Columbia	445	368	231	205
Alberta	807	511	528	488
Saskatchewan	44	41	57	97
Manitoba	642	601	500	366
TOTAL	1938	1521	1316	1156

2. BRITISH COLUMBIA

2.1 EMISSIONS AND CONTROL TECHNOLOGY

Sulphur Emissions in a Coastal Area

Sources of sulphur emissions on Vancouver Island have now been identified. The major contaminants are sulphur oxides and total reduced sulphur compounds. The major sources are pulp mills which use sulphur-bearing oil as their main source of fuel. Data on the rate of sulphur emissions in the area suggest that the level of sulphur pollution on Vancouver Island could be reduced substantially if the high-sulphur oil were to be replaced with fuels such as natural gas or low-sulphur oil.

Report: A report describing the data and their interpretation, is available from the Waste Management Branch, Ministry of Environment, British Columbia.

Inventory of Air Emissions: British Columbia

Joint work involving the Ministry of Environment, and Environment Canada is complete. A description of this work is in Section 8.

Report: See Section 8.

Inventory of Air Emissions in Greater Vancouver

The Greater Vancouver Regional District, in collaboration with Environment Canada and the British Columbia Ministry of Environment has completed an inventory of the emissions of sulphur oxides, nitrogen oxides, particulates, carbon monoxide, and volatile organic compounds. The inventory (which began in 1985) includes all sources – mobile sources, point sources, and automotive sources – in the lower Mainland.

Report: See Section 8.

2.2 AIR QUALITY AND DEPOSITION

Precipitation Chemistry Stations

The province of British Columbia continued to monitor weekly precipitation with automatic collectors at Cranbrook, Kamloops, Kitimat, Kelowna, Nanoose, Port Hardy, Pender Island, Seymour Dam, Smithers, Squamish, Spectacle Lake, Vancouver (airport), and Victoria.

These monitoring stations provide weekly data on the rate of sulphate deposition, from which is calculated the annual rate of deposition. The values for 1986, expressed in kilograms per hectare per year (kg/ha/yr) are: Cranbrook 5.1, Kamloops 2.0, Kitimat 12.4, Nanoose 5.9, Pender Island 5.7, Smithers 1.7, Squamish 16.4, Spectacle Lake 4.9, and Victoria Airport 17.1 (estimated).

Annual rates of sulphate deposition for 1986 at Kelowna, Port Hardy, Seymour Dam, and Vancouver are not available and cannot be estimated because the data were incomplete.

Report: The annual acid precipitation monitoring reports for 1984, 1985 and 1986 are available from the Waste Management Branch, Ministry of Environment, British Columbia.

High Elevation Fog Water Chemistry in North Vancouver

The province of British Columbia is studying the chemical composition of fog in order to understand the potential impact of atmospheric pollutants on high-altitude ecosystems in south-western parts of the province.

The first step in this process is a pilot study of fog water chemistry, now underway in North Vancouver. Samples are being collected by passive collectors at two high-elevation sites in Mount Seymour Park, 790 metres and 1000 metres respectively.

Report: An interim report will be available in late 1988 from the Waste Management Branch, Ministry of Environment, British Columbia.

2.3 SURFACE WATERS

pH Tolerance of Aquatic Plants of British Columbia

The study of the pH tolerance of aquatic plants of British Columbia is being conducted in three parts. Part 1, which is still underway, is a literature review of the pH limits of aquatic plants of the world. Part 2 involved analysis of existing environmental data relative to the presence of species of aquatic plants in British Columbia. Part 3 will involve experimental work to determine pH limits for some common aquatic plants for British Columbia.

Report: A report on Part 2 and data are available from the Water Management Branch, Ministry of Environment, British Columbia.

Lake Trend Monitoring

Monitoring is being conducted to determine whether acidic inputs are causing a significant deterioration of water quality. Water samples are collected monthly at six sensitive lakes in the south-western part of the province: Vancouver Island, Saltspring Island, and in the Lower Mainland. Analysis of these samples includes pH, alkalinity, acidity, general ions and metals.

Also, phytoplankton and zooplankton are collected monthly from May through October. The planktonic organisms are identified, and chlorophyll-**a** is measured. On the basis of this measurement, estimates of algal biomass are made.

Maps of the distribution of aquatic plants (aquatic macrophytes) are made on the basis of surveys taken every five years. During these surveys, samples of the lake sediments are collected. The program began in 1984, and data are to be analyzed in 1989.

Report: Data are available from the Water Management Branch, Ministry of Environment, British Columbia.

Background Lake Monitoring

A sampling program to determine the sensitivity of lakes around the province continued. However, the scope of this program is now decreasing.

Report: A report on lake sensitivity is available from the Water Management Branch, Ministry of Environment, British Columbia.

Water Quality Criteria

Water quality criteria for aluminum and pH are being developed. These criteria place greatest emphasis on valued attributes of the British Columbia environment.

Report: Reports will be available in the future from the Water Management Branch, Ministry of Environment, British Columbia.

Lake Sensitivity Mapping

Lake sensitivity maps for British Columbia have been prepared.

Report: Maps are available from the Water Management Branch, Ministry of Environment, British Columbia.

2.4 SOILS AND GEOLOGY

Soil and Geology Sensitivity Mapping for British Columbia

Two maps have been prepared but are not yet published. These are: **Soil Sensitivity to Acidic Inputs;** and, **Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition.** Legends on the maps characterize mapping units for properties significant to the interpretation of sensitivity. Relative reliability of mapping is indicated. Mapping methods and sensitivity rating criteria used are based on those outlined by the Coordinating Committee on Soil and Geology Sensitivity Mapping. An accompanying report will describe methods, data sources, and observations on sensitivity ratings.

Report: Further information is available from the Waste Management Branch, Ministry of Environment, British Columbia.

Sensitive Environments to Acidic Deposition

A map of soil and geology sensitivity and lake sensitivity has been prepared. This map is a composite produced by overlaying the Lake Alkalinity map and the map of Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition. Multiple combinations of sensitivity classes from each map have been reduced to four combined sensitivity classes and portrayed on this map. Areas of co-concurrence of low lake alkalinity and low potential of soils and geology to reduce acidity are highlighted in particular. Areas of all sensitivity class combinations were calculated. Delineations on both maps were digitized and computer overlay methods were used to locate areas of combined classes, and to calculate areas. The map was prepared to aid development of acidic deposition target loadings, and to provide visual display of British Columbia environmental sensitivities for various audiences.

Report: Large format maps (1:2 000 000 scale) and page-sized maps are available from the Waste Management Branch, Ministry of Environment, British Columbia.

2.5 VEGETATION

Impact of Atmospheric Pollutants on Vegetation

This section summarizes the activities of the Ministry of Environment related to the impact of atmospheric pollutants on vegetation. The Ministry monitors the health of vegetation in various

parts of the province where plants are exposed to sulphur, fluoride and heavy metals, and in conjunction with the University of Victoria, is developing techniques to determine the sensitivity of alphine lichens found in northern British Columbia to sulphur dioxide.

The Province, in conjunction with the University of British Columbia, is conducting research on the damage to agricultural crops caused by various airborne pollutants including ozone at various concentrations and various durations.

The Ministry has an ongoing program to review the scientific world literature on atmospheric pollutants. This review covers a wide range of scientific activity, including research on primary pollutants (sulphur oxides, nitrous oxides), and secondary pollutants (ozone, heavy metals, and organic compounds).

At the international level the Ministry is involved with the Western Conifers Cooperative of the Environmental Protection Agency (USA). These two agencies are working in collaboration to estimate the impact of atmospheric pollutants on vegetation in the Puget Sound basin. A pilot study (in northern Vancouver Island) will use remote sensing techniques to measure damage to tree growth caused by sulphur dioxide. Methods developed in this pilot study will be used in the Puget Sound area.

Another international activity involving the Ministry of Environment, the Ministry of Forests, the University of Washington, and the Simon Fraser University, is a cooperative study (scheduled to begin in 1988) on the effects of air pollution on seedling trees used in reforestation programs north and south of the international boundary.

Report: All of the projects described above are recent initiatives. Reports will be published, as the projects are completed.

2.6 HEALTH

There were no activities in this area in 1987.

3. ALBERTA

3.1 EMISSIONS AND CONTROL TECHNOLOGY

Sources and Emissions Inventories

Three types of emissions inventories are prepared by the Air Quality Control Branch of the Pollution Control Division: provincial sulphur emissions, provincial nitrogen oxides emissions, and urban (Edmonton and Calgary) emissions. The sulphur emissions inventory is updated every two years. Annual sulphur emissions (sulphur dioxide expressed as sulphur) for individual plants contributing to the observed (actual) and licensed emissions of each industrial grouping are presented on a year-to-year basis along with trends in both observed and licensed sulphur emissions total. The nitrogen oxides emissions inventory is also updated every two years (offset by one year from the sulphur emissions inventory). Major industrial, transportation, and combustion sources are included. The urban sources and emissions inventory is scheduled to be updated every five years. Quantities of carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide ($S0_2$), total hydrocarbons (THC), and particulates from 12 different sources are included.

Report: The reports listed below will be available from the Air Quality Branch, Pollution Control Division, Alberta Environment.

Industrial Sulphur Emissions for Alberta 1981 to 1985 (in review).

Inventory of Air Pollution Sources and Emissions – Calgary 1982 (in review).

Inventory of Air Pollution Sources and Emissions – Edmonton 1982 (in review).

Inventory of Air Pollution Sources and Emissions in the Cities of Edmonton and Calgary, P. Truch and Bill MacDonald. PNWIS-APCA 1985 Annual Meeting.

3.2 AIR QUALITY AND DEPOSITION

Use of Manganese Chloride for Cumulative SO_2 Monitoring

The objective of this project, which began in 1987, is to find a more accurate method of measuring sulphur dioxide (SO_2) concentrations in the vicinity of sour gas processing plants. Sample tubes containing manganese chloride ($MnCl_2$) solution and equipped with SO_2 permeation membranes were tested in the laboratory for the absorption of SO_2. The absorption efficiency and effects of various environmental factors such as temperature and humidity will be studied. Although $MnCl_2$ solution has been proven to be a good absorbing reagent for SO_2, suitability of this reagent under the Alberta climatic condition still remains a major problem. We are also at present testing another sampling technique using a potassium bicarbonate soaked filter pack. If a more accurate SO_2 monitoring method is found, the existing lead dioxide (PbO_2) candle method will be replaced.

Report: The results of this program will be available from the Chemistry Wing of the Alberta Environmental Centre, Vegreville.

Determination of Organic Anions in Precipitation

A project was initiated to develop an ion chromatographic method for measuring organic anions in precipitation. Some progress has been made regarding this method. An ion chromatographic method for the determination of formate and acetate ion in precipitation sample has been established. An ion exclusion chromatographic method is in progress for the measurement of higher organic anions, such as propionate, butyrate, etc. The low concentrations of these organic anions, especially in rain samples makes the analysis sometimes very difficult, hence efforts will be made to preconcentrate the sample before the ion chromatographic analysis.

Report: Results will be available from the Chemistry Wing of the Alberta Environmental Centre, Vegreville.

Analysis of Precipitation Chemistry Measurements in Alberta

During the five-year period, 1978 to 1982, 11 precipitation stations operated in Alberta collecting precipitation samples on a monthly basis. Alberta precipitation has an average pH of 5.5, little different from the theoretical background value of 5.6. The calcium cation and sulphate anion are the most dominant species in precipitation, and more so in southern Alberta than in the northern part of the province.

The highest hydrogen ion concentrations occur in the summer months, while the concentrations of most ions have their largest values in winter. No trend from 1978 to 1982 was observed.

The average wet sulphate deposition in Alberta is 10 kilograms sulphate per hectare per year; lower than the eastern Canada target loading of 20 kilograms sulphate per hectare per year. In Alberta, unlike eastern Canada, the wet sulphate is not a direct measure of acid deposition because a large fraction of sulphate is not associated with the hydrogen ion. Corrections for sulphate associated with calcium and the relative importance of dry to wet deposition must be considered when comparing to a target loading.

Report: Copies of the following reports and papers are available from the Air Quality Control Branch, Pollution Control Division, Alberta Environment.

A Five-Year (1978 to 1982) Summary of Precipitation Chemistry Measurements in Alberta (in review).

Precipitation Quality Monitoring in Alberta. Y. K. Lau, and N. C. Das. PNWIS-APCA 1985 Annual Meeting.

Precipitation Chemistry Measurement in Alberta. H. L. Bertram, N. C. Das, and Y. K. Lau. Water, Air and Soil Pollution 30 (1986): 231-237.

Precipitation Quality Monitoring Network

The chemical composition of precipitation is monitored at several permanent sites in Alberta. The objective of the project is to detect significant changes resulting from industrialization within the province and to provide an historical database.

Report: The following reports are available from the Air Quality Control Branch, Pollution Control Division, Alberta Environment.

Precipitation Quality Data Summary 1983 and 1984 (in review).

Precipitation Quality Data Summary 1985 and 1986 (in review).

Diffusion and Deposition Modelling for Point Source Emissions

A set of models is maintained to estimate pollutant concentrations and deposition downwind of point sources. The level of input data and desired output determine the selection of the specific model to be used. New models are added and older ones are upgraded as required. Existing and proposed point sources, and complexes of point sources, are evaluated for regulatory purposes.

Occasionally, guide models are promulgated for general use.

Reports: The reports listed below will be available from the Standards and Approvals Division, Alberta Environment:

Users Manual for Alberta Environment.

Dispersion Models (in prep.):

PLUMES2	Users Guide
STACKS2	Users Guide
SULDEP3	Guide
ADEPT	Guide
SEEC	Users Guide

A Comparison of Mesoscale Acid Deposition Models as Applied to Northern Alberta and Saskatchewan

This project will attempt to assess and evaluate the overall performance of three acid deposition models (MESOPUFF2, RELMAP, SERTAD), with respect to their acid deposition prediction capability. Model results will be objectively compared to field observations for a period of 3 months (June to August). The models will be ranked by overall performance, cost effectiveness and suitability for application in northern Alberta and Saskatchewan.

Report: A report will be available from Alberta Environment in 1988.

Calculation of Summer Aerosol Profiles Over Central Alberta

The primary objective of the project is to determine the average summer profiles of atmospheric aerosol number-size distributions over central Alberta. Additionally, the project will determine the profile particle extinction coefficients. The data will be extracted from data collected by the instrumented aircraft of the Alberta Research Council in the summer of 1984 over central Alberta. Extinction coefficients will be calculated using the Mie theory for coated spheres and measured or assumed aerosol chemical characteristics.

Report: A report, prepared by the Alberta Research Council, is to be submitted to the Atmospheric Environment Service.

3.3 SURFACE WATERS

Lake Monitoring Network

The objective of this project is to establish long-term databases which can be used to identify changes in trophic state or acidification status. Long-term monitoring has been initiated on four lakes in central Alberta (Wabamun, Nakamun, Baptiste, Ethel). The lakes have been sampled at monthly intervals since 1983.

Report: Data are available from the Water Quality Control Branch, Pollution Control Division, Alberta Environment.

Lake Survey Program

This survey was designed to upgrade the lake water quality database in certain areas of the province identified as containing lakes sensitive to acidic deposition. The water quality database in the northern upland regions of the province is small and represents an amalgamation of historical data from various sources. A limited survey program was initiated in northern Alberta to validate and upgrade these historical data.

Report: Data are available from the Water Quality Control Branch, Pollution Control Division, Alberta Environment.

3.4 SOILS AND GEOLOGY

Determination of Interim Target Loading Values for Acid Inputs to Alberta Soils

The objective of this report is to determine an interim target loading number for selected Alberta soils using the Boom and Grigal (1985) computer simulation model. The model will be run for each of six Alberta soils selected to predict (1) changes in soil chemical properties (soil pH, exchangeable bases, and soil solution aluminum) with time for a given loading rate, and (2) annual deposition rates (i.e., target loading values) from a specified change in soil pH and exchangeable bases over a given period of time. The model simulations will be run using current loading rates based on effective acid inputs derived from actual air and precipitation chemistry data; and a range of loading rates both above and below the current loading rate. For each of the six soils, target loads that would cause a decrease in soil pH of 0.5 to 2 units and a loss of 10% to 20% of exchangeable bases over 25, 50, and 100 year periods will be predicted.

Report: A report on the first year of research will be available from Alberta Environment in 1988.

Target Loading for Soil Chemistry: Buffering Capacity of Soils

The objective of this report is to develop a database of soil properties, specifically acid buffering capacity, aluminum solubility, and general soil characteristics, related to acidity and ion exchange properties. Analysis and experimentation will be performed on soils primarily in the Athabasca Oil Sands and foothills regions of Alberta which are considered highly or moderately sensitive to acid deposition. Soil samples will be analyzed by standard methods for pH, cation exchange capacity, exchangeable cations, exchange acidity, soluble aluminum, aluminum forms, and mineralogy. The solubility of aluminum in relation to other soil properties and acid buffering capacities will be determined.

Report: A final report will be available from Alberta Environment in the fall of 1988.

Long-Term Measurement of the Acidification of Non-Cultivated Soils in Alberta

Eight monitoring sites have been established to measure the acidification of soils over a long period of time in areas where deposition of industrial acid precursors is expected to occur. The monitoring sites are intended to measure the worst situations, hence they will act as soil acidification early warning sites. Two sites have been sampled each autumn since 1981. All sites will be resampled once every four years.

Report: A brief synthesis of procedures is available from the Earth Sciences Division, Alberta Environment.

3.5 VEGETATION

There were no activities in this area in 1987.

3.6 HEALTH

Health Effects of Sulphur Gases

Research is being conducted by the Alberta Environmental Centre for three government departments to determine the effects of toxic or potentially toxic gases, vapours, particulates, and aerosols on animals, and by extrapolation, on man. A series of 19 studies on the pathological, biochemical, and cytological effects of single acute exposure of rats to various concentrations of hy-

drogen sulphide have been completed and a second study is being planned currently. **In vitro** studies of sulphide toxicity are continuing.

Report: There are 39 reports and publications available from the Animal Sciences Wing of the Alberta Environmental Centre, Vegreville.

4. SASKATCHEWAN

4.1 EMISSIONS AND CONTROL TECHNOLOGY

Saskatchewan Air Emissions Inventory of Sulphur Dioxide and Nitrogen Oxides

The inventory of sulphur dioxide and nitrogen oxides emissions is being updated for 1985. The inventory will be prepared according to the methods outlined in the emissions inventory methods manual developed by the Western Canada LRTAP Inventory Technical Working Group.

Report: A final report is available from the Air and Land Protection Branch, Saskatchewan Environment and Public Safety.

4.2 AIR QUALITY AND DEPOSITION

Poplar River Thermal Power Plant Ambient Air Monitoring Program

Saskatchewan Environment and Public Safety monitors sulphur dioxide and suspended particulates at one location, Coronach. Few detectable concentrations have been recorded at this site. The highest hourly concentration recorded in 1987 was 0.071 ppm, well below the provincial standard. The 24 hour average suspended particulates concentrations were within the provincial standards.

Report: Data summaries are available from the Air and Land Protection Branch, Saskatchewan Environment and Public Safety.

4.3 SURFACE WATERS

Surface Water Sampling in Northern Saskatchewan

Approximately 60 surface water stations in northern Saskatchewan are monitored. Most of the samples are collected by industry at the request of Saskatchewan Environment and Public Safety.

Report: Data summaries are available from the Mines Pollution Control Branch, Saskatchewan Environment and Public Safety.

4.4 SOILS AND GEOLOGY

Soils and Geology Sensitivity Mapping

Maps of Saskatchewan depicting soils and geology sensitivity to acid precipitation have been prepared by the Saskatchewan Institute of Pedology. The maps have been modified at the borders to match up with the maps being prepared by Manitoba and Alberta. The maps are based on the criteria outlined by the Co-ordinating Committee on Soils and Geology Sensitivity Mapping.

The initial mapping exercise identified a large triangular area in northwestern Saskatchewan where no data existed. In 1986 the Saskatchewan Institute of Pedology collected the data necessary to fill the data gap. The soils and geology sensitivity maps have been updated to include this data.

Report: The maps and a report are available from the Air and Land Protection Branch, Saskatchewan Environment and Public Safety and the Saskatchewan Institute of Pedology.

4.5 VEGETATION

No specific monitoring activities or studies were conducted with respect to vegetation response to acidic deposition in 1987.

4.6 HEALTH

Long-Range Transport of Air Pollutants-Health Effects

A joint epidemiological study between Health and Welfare Canada and Saskatchewan Environment and Public Safety began in 1985 on school-aged children to assess the potential risk to human health from the long-range transport of air pollutants. Details of this study are outlined in Section 8.6.

5. MANITOBA

5.1 EMISSIONS AND CONTROL TECHNOLOGY

Emission Inventories

No specific studies are underway with respect to emissions and control technology. However, emission inventories for nitrogen dioxide and sulphur dioxide are being maintained by the province.

Report: A report of nitrogen dioxide and sulphur dioxide emissions for 1986 has been completed. Data summaries for succeeding years are also available from Manitoba Environment and Workplace Safety and Health.

5.2 AIR QUALITY AND DEPOSITION

Air Quality Monitoring in Northern Manitoba

Atmospheric sulphur dioxide was measured until April on a continuous basis downwind from the two major non-ferrous smelters at Flin Flon and Thompson. The network consisted of two stations within the Flin Flon area and one in Thompson. Total reduced sulphur compounds were measured at one site near the MANFOR kraft pulp and paper mill at The Pas. Levels that exceed the provincial air quality objectives/guidelines were observed on several occasions, primarily because of meterological conditions.

Report: Data summaries and reports are available from Manitoba Environment and Workplace Safety and Health.

Precipitation Monitoring

Precipitation is sampled on a daily basis at Norway House, Island Lake, Gillam, Brochet, Winnipeg, and Pointe du Bois. The following variables are analyzed: pH, conductance, acidity, sulphate, nitrate, chloride, calcium, ammonium, magnesium, sodium, and potassium. Annual volume-weighed mean pH levels are about 5 pH units in remote areas, levels at Winnipeg are higher. Wet sulphate deposition values are at levels near background and range from 4 to 6 kilograms per hectare per year.

Report: Data summaries and reports are available from Manitoba Environment and Workplace Safety and Health.

Snowpack Survey

A winter snowpack survey is being conducted within the boreal forest ecosystem surrounding the smelters in Flin Flon and Thompson. Several sampling sites are located around Flin Flon and twelve near Thompson. At each site replicate samples are taken and analyzed for pH, sulphate, zinc, lead, copper, nickel, iron, cadmium, and arsenic. The snowpack survey includes 18 stations throughout the province. Samples are analyzed for pH, conductance, acidity, sulphate, nitrate, chloride, calcium, ammonium, magnesium, sodium, and potassium.

A report is available for the sampling carried out near Flin Flon during the period 1981-83. Analysis of the data from the Flin Flon area for the period of 1983 indicates that zinc is the major metal found in snow; however, copper, iron and lead are also found. The amounts of these metals all decrease in the snow with distance from the smelter. Small amounts of cadmium are also found but there is not a clear relationship with distance from the smelter. Sulphate deposition is highly variable, but there is a general decreasing trend away from the smelter. The pH of the snow is variable and, in most cases, is greater than 5.6 pH units. Deposition of zinc, copper, iron, lead, and cadmium decreased markedly from 1982 to 1983. The decrease is attributed to the installation of a new electrostatic precipitator on the zinc smelting process at the Flin Flon Smelter in November, 1982.

Cursory examination of the data from the Thompson area indicates that nickel and copper are deposited as far away as 12 km from the smelter. Snow pH does not seem to be affected by the smelter emissions. A report on snow deposition between 1982 and 1985 is available. Cursory examination of the data collected throughout the province indicates that the sulphate deposition is generally less than 1 kilogram per hectare per year. Depressed pH values (below 5.6 pH units) have been recorded at most sites, but not consistently. The lowest pH reading was recorded at Island Lake (pH 4.5).

Report: Data summaries or reports or both, are available through Manitoba Environment and Workplace Safety and Health.

5.3 SURFACE WATERS

Surface Water Sampling

No specific water quality sampling related to LRTAP was carried out. However, information from monitoring of previous years is available.

Report: Data summaries are available through Manitoba Environment and Workplace Safety and Health.

Aquatic Sensitivity Mapping

Aquatic sensitivity maps were prepared for inclusion with the overall aquatic sensitivity maps of western Canada. Aquatic areas sensitive to acid deposition have been found in the northwestern corner of the province and east of Lake Winnipeg.

Report: Data summaries are available through Manitoba Environment and Workplace Safety and Health.

5.4 SOILS AND GEOLOGY

Terrestrial Sensitivity Mapping

Terrestrial sensitivity mapping was completed in cooperation with other jurisdictions of western Canada. Considering surface soils and bedrock characteristics, areas of high sensitivity to acid deposition were found on the east side of Lake Winnipeg and in the northwest corner of the province. In these areas the potential of soils and bedrock to reduce the acidity of incoming acidic deposition is low, indicating a high sensitivity to acid rain.

Report: Two maps have been produced at a scale of 1:2,000,000. These are:

1. Sensitivity of Soils to Acidic Inputs.
2. Potential of Soil and Bedrock to Neutralize the Acid of Incoming Acidic Deposition.

A report including both maps is available through Manitoba Environment and Workplace Safety and Health.

5.5 VEGETATION

Vegetation Studies Around Northern Smelters

Studies of coniferous regeneration response to heavy metal contaminated soil in the vicinity of mining and smelting complexes at Thompson and Flin Flon continue. A report on effects determined near the Inco smelter in Thompson has been released and work continues in the Flin Flon area. These greenhouse studies have shown that metal contaminated soil are inhibiting root growth of 24 week old seedlings of Black Spruce and Jack Pine. Of concern is a decline in natural regeneration of forests within 5 km of mining smelters.

Report: Reports are available from Manitoba Environment and Workplace Safety and Health.

Tree Regeneration Study Near Thompson

Field plantings of Black Spruce and Jack Pine at Thompson are continuing with plans to initiate similar plantations at Flin Flon. These studies are a follow up of greenhouse studies and are to determine effects of heavy metal contaminated soil on seedlings. Growth and development of root and shoot growth are being evaluated.

Report: The study is ongoing. Interim results are available from Manitoba Environment and Workplace Safety and Health.

Terrestrial Monitoring

Eight forest monitoring sites are being routinely monitored in areas sensitive to acidic deposition throughout the province. This program is being carried out in cooperation with the Canadian Forestry Service's ARNEWS program.

Report: Baseline data has been collected and data summaries are available from Manitoba Environment and Workplace Safety and Health.

5.6 HEALTH

Cadmium in Moose

Cadmium levels in moose kidney and liver have been monitored since 1985. This program is in response to concerns for potential mobilization of cadmium from soils as a result of acidic deposition. Cadmium concentrations in 1987 ranged from 0.4 to 42.7 ug/g in kidney and 0.1 to 22.3 ug/g in liver.

The Manitoba Department of Health has issued recommendations to hunters that kidneys of moose not be consumed and that liver consumption be limited. Monitoring of moose continues and has been expanded to include deer, elk, wolf, coyote and bear. This program is a cooperative study between Manitoba Environment and Workplace Safety and Health, as well as Manitoba Natural Resources and the Wildlife Toxicology Fund of Environment Canada.

Report: An interim report is available from Manitoba Environment and Workplace Safety and Health.

6. NORTHWEST TERRITORIES

6.1 EMISSIONS AND CONTROL TECHNOLOGY

No activities were conducted in this area.

6.2 AIR QUALITY AND DEPOSITION

Aerosol Deposition

The Northwest Territories is supporting a three-year study of aerosol deposition in snow cores, lake bottom sediment, and glacial ice in the central arctic. The study is being undertaken by Mr. Dennis Gregor, of the Inland Waters Directorate, Regina, Saskatchewan.

Report: Further information is available from the Inland Waters Directorate, Regina, Saskatchewan.

Arctic Haze

Solar radiometric techniques were employed to exhibit the potential of this methodology for the monitoring of arctic haze. The Alberta Research Council, Resource and Technologies Department, undertook this study on behalf of the Northwest Territories. The technique was successful in detecting arctic haze concentrations. The Pollution Control Division also took snow core samples at Baker Lake during this program.

Report: A report "Monitoring Arctic Haze using Radiometric Techniques" is available from the Pollution Control Division, Department of Renewable Resources, Government of the Northwest Territories.

Precipitation Chemistry

A CAPMON station is being installed at Snare Rapids near a hydro-power station located approximately 200 kilometres north of Yellowknife.

Report: Contact the Pollution Control Division, Department of Renewable Resources.

6.3 SURFACE WATERS

Aquatic Sensitivity Mapping

The aquatic sensitivity map was completed by the Inland Waters Directorate in Regina, Saskatchewan.

Report: The report on aquatic sensitivity to accompany the map was completed by the Inland Waters Directorate in Regina, Saskatchewan.

6.4 SOILS AND GEOLOGY

There were no activities conducted in this area.

6.5 VEGETATION

There were no activities conducted in this area.

6.6 HEALTH

Polar Bear Study

The Northwest Territories Wildlife Service and the Canadian Wildlife Service continued to take tissue samples from polar bears to measure the concentrations of polychlorinated biphenyls (PCB) and other organochlorides.

Report: Further information is available from the Wildlife Service, Department of Renewable Resources (Yellowknife) and the Canadian Wildlife Service (Edmonton).

Blood Samples – Native Population

The study of polychlorinated biphenyls (PCB) concentrations in the native people of Broughton Island continued. This study, conducted by the federal Departments of Health and Welfare, Indian and Northern Affairs, and Fisheries and Oceans, is based on the analysis of PCB concentrations in breast milk and blood, and in the diet of the people.

Report: Further information is available from Health and Welfare Canada (Ottawa).

Fish Samples – MacKenzie River

The Department of Fisheries and Oceans sampled burbot livers in fish taken in the Fort Norman area after complaints about their taste and appearance. The presence of toxaphene and other organochlorides were detected in the fish specimens. The source of these pollutants are believed to be long-range transport of air pollutants.

Report: Further information is available from the Department of Fisheries and Oceans (Yellowknife).

7. FEDERAL GOVERNMENT

7.1 EMISSIONS AND CONTROL TECHNOLOGY

Current Acid Gas Emission Control Options for Western Canada – A Review

A review of proven control technologies applicable to major emission sources of sulphur dioxide and oxides of nitrogen in western Canada is presented, without regard to cost. The review is based on the belief that future expansion of the western economy will undoubtedly cause increased emissions of these acid rain precursors, requiring both industry and government to maintain continuing vigilance against LRTAP. Control technologies for sulphur dioxide covered the natural gas, thermal power, oil sands and non-ferrous smelting industries. For nitrogen oxide, controls in the areas of transportation, thermal power industry, natural gas industry, oil sands industry and residential and commercial heating were reviewed.

Report: The report is available upon request from the Western and Northern Region, Environmental Protection, Conservation and Protection, Environment Canada, Edmonton.

Inventory of Point Sources and Emissions in British Columbia

A contract study was completed for an inventory of point source emissions (year 1985) for the five common air contaminants, polycyclic aromatic compounds, lead, cadmium and vanadium. This data will be combined with the mobile and area source inventories in preparation by Conservation and Protection, and the emissions inventory prepared for the Greater Vancouver Regional District to provide a comprehensive emissions inventory for the Province.

Report: Information is available from the Pacific and Yukon Region, Environmental Protection, Conservation and Protection, Environment Canada, West Vancouver.

Volatile Organic Compound Emissions From Gasoline Marketing Operations

As part of the Lower Mainland Oxidant study, an emissions inventory for volatile organic compounds has been developed. The report will provide emission rates of volatile organic compound species and spatial and temporal resolution for all fuel handling operations from refinery gate to vehicle refueling. The data will be in a form to facilitate photochemical oxidant modelling.

Report: Information is available from the Pacific and Yukon Region, Environmental Protection, Conservation and Protection, Environment Canada, West Vancouver. A report is expected in 1988.

7.2 AIR QUALITY AND DEPOSITION

Oceanic Background Sources of Chemicals Contributing to Acidity in Marine Precipitation

A joint program of the Atmospheric Environment Service and the Institute of Ocean Sciences (IOS), Fisheries and Oceans Canada, has established an acid rain/LRTAP laboratory at IOS, Sydney, British Columbia. A sampling program is being conducted on an opportunity basis to collect marine precipitation on research ships with cruise tracks in British Columbia coastal waters and open-ocean waters west of Vancouver Island to Station P (50°N 145°W) in northeast Pacific Ocean. These samples will be analyzed for pH, chloride (Cl^-), sulphate ($SO_4^=$) and nitrate (NO_3^-) to establish the long-term trends in the atmosphere over marine waters.

Report: Further information is available from the Institute of Ocean Sciences, Department of Fisheries and Oceans, Sidney, British Columbia, Attention: C. S. Wong.

Hydrometeorology of the CANSAP Sampler

To determine the evaporative loss and undercatch of the CANSAP sampler, CANSAP and CAPMON samplers have been installed at the Regina Airport. Samples are weighed daily, and a comparison of the sample weights is made. Sampling was completed in 1987 and focused solely on evaporative losses. Preliminary results indicate significant daily evaporative losses from the CANSAP sampler but greatly reduced evaporative losses have been achieved with the improved design of the CAPMON sampler.

Report: Further information is available from the Central Region, Atmospheric Environment Service, Regina. A final report on the project is expected to be completed in 1988.

Canadian Network for Sampling Precipitation (CANSAP)

Stations in this network have samplers that open only during precipitation events. Samples are removed daily and analyzed on a monthly basis for pH, conductivity, sulphate, nitrate, chloride, ammonium, potassium, sodium, magnesium, and calcium. In 1986, the CANSAP network was discontinued with the following exceptions. Stations at Port Hardy, Vancouver and Kelowna in British Columbia were replaced by provincial government precipitation sampling stations and AES assisted the provinces in their operation. In Alberta, the station at Coronation was continued through 1987 and another CANSAP sampler was operated at Esther to provide comparative data with Esther CAPMON station.

Report: The report CANSAP DATA SUMMARY 1984-1985 was released in 1987 and will be the last publication for this network. Information is available from the regional offices of the Atmospheric Environment Service, and data summaries can be obtained from: the Air Quality and Inter-Environmental Research Branch, Atmospheric Environment Service, Downsview, Ontario.

Canadian Air and Precipitation Monitoring Network (CAPMON)

CAPMON is a regional scale air and precipitation monitoring network with siting criteria and sampling protocols much more stringent than that of the CANSAP network. Daily samples are analyzed for the same ions as for CANSAP (see above). The western Canada portion of the network in 1987 consisted of the following:

Manitoba
- McCreary
- Island Lake

Saskatchewan
- Cree Lake

Alberta
- Esther

In 1987, a site for the southwestern British Columbia CAPMON station was selected on Sturna Island. Equipment will be installed and operation will commence in 1988.

A site was selected for the NWT CAPMON site at Snare Rapids, NWT which is located 135 km northwest of Yellowknife. It is proposed that the program at Snare Rapids will be a joint venture between Environment Canada and the Renewable Resources Department of the Government of the Northwest Territories. Equipment will be purchased and installed by AES and ongoing operation and maintenance will be assumed by the Government of the Northwest Territories. Final site selection will be in early 1988 with installation expected during summer 1988.

Report: Data summaries of precipitation chemistry are published annually and are available from the Atmospheric Environment Service, Downsview, Ontario.

British Columbia Transboundary Precipitation Chemistry

Data gathering from the South Coast British Columbia (SCBC) precipitation event sampling network ceased in December 1986 but analysis of data collected continued in 1987. A report on the preliminary analysis of data gathered before and after the closure of the ASARCO smelter in Tacoma, Washington indicated a marked reduction in precipitation arsenic concentrations in British Columbia and suggested decreases in sulphate and nitrate concentrations as well. A second analysis using a subset of the data (from samples analyzed at one laboratory only) supported the preliminary indication of a reduction in arsenic and sulphate levels but indicated no change in nitrate levels. Coincident reductions in levels of vanadium appear not to be related to the smelter closure but remain unexplained.

Report: A limited number of copies of the reports **The Effect of a Major Emitter on the Rain Chemistry of Southwestern British Columbia – a Preliminary Analysis,** Part I and Part II (Data Listings), Reports PAES 87-1 and PAES 87-2 respectively, are available from the Pacific Region, Atmospheric Environment Service, Vancouver. Also available from the same source is an extended abstract of a paper presented at the Pacific Northwest International Section of APCA held in Seattle, November 1987: **The Effect of a Major Emitter on the Rain Chemistry of Southwestern British Columbia – a Second Look.**

Bibliography of Acid Rain Literature for Western Canada

An annotated bibliography of literature related to acid rain in western Canada was compiled.

Report: Copies of the report **An Annotated Bibliography of Literature Related to Acid Deposition in Western Canada** are available from the Pacific Region, Atmospheric Environment Service, Vancouver.

Western Canada Deposition Modelling (Statistical LRTAP Models)

The Regional Climate Dispersion Model (RCDM), Ontario Ministry of Environment Model (OME), and the Fisher Model have been run using input data tuned to western Canada. Sulphur dioxide emissions for current conditions over western Canada and the North American 1980 inventory have been incorporated in model runs.

Model input parameters will be adjusted and further runs will be executed. Comparisons between models and between various individual model runs will be conducted.

Report: Information is available from the Western Region, Atmospheric Environment Service, Edmonton, Alberta. An interim report on the work will be completed by the end of March, 1988.

Regional Trajectories

The Atmospheric Environment Service (AES) is evaluating the ability of existing trajectory models to produce regional-scale trajectories based on available data in the regional computer in Edmonton and the mainframe computer in Downsview, Ontario. A comparison of trajectories produced by smaller scale regional wind models and the AES trajectory model is continuing. Trajectories produced will be verified against analyzed wind fields and aircraft tracking data where available. Comparison of modelled trajectories will be completed in 1988.

Report: Further information is available from the Western Region, Atmospheric Environment Service, Edmonton, Alberta.

7.3 SURFACE WATERS

ACID DEPOSITION IMPACT STUDIES

Pilot Biomonitoring Program

The objectives of the program are:

a. To determine whether biochemical and histological changes are measurable in hatchery fish reared in stream water subject to episodic pH depression.

b. To collect and archive stream invertebrate samples for later taxonomic analysis in support of results from fish sampling.

c. To collect, or assist in the collection of appropriate water chemistry data.

The study components are:

a. Fish Stress Tests Hatchery fish at selected sites will be sacrificed and sampled for the following sublethal stress indicators:

1. Blood chemistry
   - Sodium, potassium, calcium and chloride
   - Blood osmolality
   - Blood glucose
   - Blood protein
2. Tissue chemistry
   - Liver glycogen
   - Muscle glycogen
   - Kidney ascorbic acid
3. Tissue histopathology
   - Gill micro-examination.

b. Benthic Invertebrate Sampling
Invertebrates will be sampled with a modified Surber sampler, preserved and archived.

c. Water Chemistry
Water chemistry will be sampled in fish rearing troughs and, through a cooperative program, in streams supplying the hatcheries.

Report: Further information on the pilot biomonitoring program is available from the Fisheries and Oceans Canada, Pacific Region, Vancouver.

Biological Exposure Indicators for Metals Discharged by a Smelter

Eight lakes, four in Manitoba and four in Saskatchewan, were selected to evaluate effects on fish, crayfish, and zooplankton of atmospheric deposition of metals discharged by the smelter in Flin Flon, Manitoba. Lakes in Manitoba ranged from 10 to 31 km from the smelter. Lakes ranged from 40 to 677 hectares in surface area, and from 3.0 to 24.4 metres in maximum depth. Water chemistry parameters demonstrate wind distance and wind direction dependencies in sulphate deposition. These lakes, however, are not acidified (pH values range from 7.4 to 8.3). Four sediment cores, obtained by SCUBA diving were removed from the deepest portion of each lake. Cores were sectioned and analyzed for cadmium, copper and zinc. Metal profiles for these sectioned cores will be presented to quantify metal deposition since the beginning of smelter operations in 1930. Analyses of blood from two fish species, northern pike and white sucker, for concentrations of cells and electrolytes (sodium, potassium, calcium, glucose, and osmolality) indicate that osmoregulatory

failure is **not** being produced by these metal loadings. Preliminary analyses of liver from these fish indicate that low-molecular-weight metal-binding proteins (metallothioneins) are increased in metal-exposed fish. These proteins are correlated with increased tolerance to metal toxicity, and may serve to protect these fish from adverse effects produced by the metals. Several radiotracer displacement methods for rapid analyses of these proteins were evaluated and modified for use on aquatic biota. Using the modified method, metallothioneins will be analyzed in fish liver and kidney, crayfish hepatopancreas, and whole zooplankton to determine their sensitivity and applicability as biological indicators of metal exposure.

Report: A report is available from the Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba. This work was funded equally by LRTAP and the World Wildlife Foundation.

Experimental Lakes Area (Northwestern Ontario)

In Lake 223, experimentally acidified since 1976, direct toxicity effects of hydrogen and food chain effects on the biota had been observed at relatively high pH values (5.5-6.0) and many species were lost from the food chain. During 1987, a partial recovery phase was continued for the fourth consecutive year, with the mean epilimnetic pH controlled near 5.5. Almost none of these species lost during acidification have returned and lake trout reproduction remains poor. A further stage of recovery (pH 5.8) is planned for 1988.

In Lake 302, a double-basin acidification study has been underway since 1980. The pH of the south basin, receiving additions of sulfuric acid, has been reduced to 4.8 and food chain observations are continuing. As in Lake 223, a number of species have been lost and some new species have appeared. Additions of nitric acid to the north basin were discontinued. However, the pH of this basin was lowered to approximately 5.5, using hydrochloric acid, to study the effects of lowered pH on bacteria controlling the nitrogen cycle.

A pulse acidification of Lake 225 used hydrochloric acid to lower the pH of this small, brown water lake from approximately 5.0 to 4.5 over a two day period. The transmission of light and the plankton populations were closely monitored before, during and after this pH pulse.

A whole lake cadmium experiment began on Lake 382 during 1987. This involved additions of both radiotracer and "cold" cadmium to delineate ecological pathways and physiological effects. The experiment is expected to continue for several more years.

A wetland acidification experiment, underway since 1983, continues on the Lake 239 bog. Effects on outflow chemistry are being monitored and the direct effects on flora and insect fauna are under observation.

Background monitoring was carried out on a small terrestrial watershed in preparation for a possible acidification study. Weirs were installed to permit closer evaluation of flows and chemical mass balances.

Report: Further information is available from the Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba.

MONITORING

Pacific Region Baseline Surface Water Chemistry Monitoring

Weekly surface water data collection (pH alkalinity, conductivity and colour and metals, seasonally) was conducted on selected lower order salmon streams in the Pacific Region in 1986. Monitoring was concentrated in the Vancouver and Lower Mainland area where localized depositions may be having impacts on surface water quality. Episodic pH depressions and conditions of consistently low alkalinity have been documented.

Report: The 1985-86 data will be published early in 1988 in Canadian Technical Report 1599, **Assessment of Acidification Potential of Selected Lower Mainland and Vancouver Island, British Columbia Streams.** The report and further information are available from the Fisheries and Oceans Canada, Pacific Region, Vancouver.

Water Chemistry Sampling – Northwest Territories

Water Quality Branch of Western and Northern Region, Inland Waters/Lands, Environment Canada, collects water samples from major ion and metals analysis at a total of 44 sites in the Northwest Territories. Some of these sites are appropriate for LRTAP surface water monitoring.

Report: Further information is available from the Inland Waters/Lands, Environment Canada, Yellowknife.

Water Chemistry Sampling – Prairie Provinces

Environment Canada monitors a large number of surface water sites in the prairie provinces on a monthly basis, or at the time of visit. This monitoring is conducted as part of the Water Quality Branch program or as a result of agreements with the provincial governments or agencies. Periods of record of ten or more years are the average and are useful for assessing LRTAP effects.

Report: Further information is available from the Inland Waters/Lands, Environment Canada, Regina.

Aquatic Sensitivity Mapping – Saskatchewan, Manitoba, Northwest Territories

Environment Canada supported the aquatic sensitivity mapping of Saskatchewan, Manitoba, and the Northwest Territories by providing database development and computerized isotherm mapping of indicator parameters.

Report: The activity is completed. Information will be published in 1988 with other data for western Canada (see Chapter 8). Further information is available from the Inland Waters/Lands, Environment Canada, Regina.

Water Quality Study of Elk Island National Park

Inland Waters/Lands, Environment Canada and Parks Canada, have cooperated on a water quality study of Elk Island National Park. This study attempted, among other things, to assess the relative impact on the Park's aquatic environment of industrial activities nearby. Intensive sampling to detect the deposition of acidic, organic or other related contaminants, has been undertaken. Sampling included lake water, bottom sediments, biota, ground water and snow.

Report: A report will be issued in 1988. Further information is available from the Inland Waters/Lands, Environment Canada, Regina.

7.4 SOILS AND GEOLOGY

Yukon Soils and Geology Sensitivity Mapping

The objective of the project is to produce maps of: (1) the potential of soil and geology to reduce the acidity of incoming acid deposition affecting the aquatic resource and (2) soil sensitivity to acid deposition affecting vegetation.

Report: Information will be published in 1988 with other data for western Canada (see Chapter 8). Further information is available from the Canadian Forestry Service, Victoria.

7.5 VEGETATION

Acid Rain National Early Warning System (ARNEWS)

The Acid Rain National Early Warning System was established to clearly and accurately detect early signs of acid rain damage to forests before damage becomes obvious. A nationwide network of permanent plots has been established by the Canadian Forestry Service to detect and monitor changes in forest soil, vegetation and trees.

The objective of the program is to obtain baseline data on the concentrations of foliar and soil elements, foliar and tree conditions (including insect and disease levels), and tree growth. The baseline studies are to be followed up by detection and monitoring of possible changes to the baseline conditions over a planned 20-25 year period.

Fifteen nationally standardized forest plots have been established as part of the ARNEWS program in British Columbia. Detailed soil and foliar chemical analyses are now available for all 15 British Columbia plots. Baseline data have been obtained. Acid rain injury was not readily observable. Yearly monitoring of vegetation condition will continue.

To obtain a more immediate assessment of the condition of the forest in British Columbia, Forest Insect and Disease Survey (FIDS) undertakes subjective observation of the province wide permanent sample plots. To date, additional observations have been made on 592 plots. Any damage observable was usually attributed to previous or current pest conditions.

In the Prairie Provinces, the FIDS unit has established 12 ARNEWS plots: five in Alberta, three in Saskatchewan and four in Manitoba. All plots conform to the nationally standardized reporting format and are scheduled to remain in existence for 20-25 years.

Report: Further information is available from the Canadian Forestry Service, Victoria and Edmonton.

Biomonitoring Studies on Selected ARNEWS Plots

Thirty-four subplots were established in five British Columbia ARNEWS sites. Presence, health and percent cover of terrestrial mosses, lichens, and liverworts were recorded. Six perma-

nent arboreal subplots were established and pollution sensitive lichens transplanted. Preliminary results show no visible damage to any of the plants.

Report: Further information is available from the Canadian Forestry Service, Victoria. No further work was done in 1987.

Literature Survey for Chemical Stress Indicators in Conifers

There are a number of published reports indicating that under controlled laboratory conditions conifers undergo stress induced chemical changes. Induced chemical changes can be caused by acid rain or other atmospherically deposited substances deleterious to conifers. However, when these studies are repeated under normal environmental conditions such chemical responses are, often, no longer discernible.

Chemicals that are part of the primary metabolic systems which are essential to the life of the plant, such as carbohydrates and amino acids are essential to the survival of the plant and thus will be the last to undergo substantive, or long-term changes in response to stress, as any potable change in these essential chemicals might well lead to the death of the plant. It may prove to be more worthwhile to examine the literature in detail for evidence of some secondary chemical changes to demonstrate cause and effect of air pollutants, or other stress inducers, on the internal chemistry of plants under stress.

An in-depth literature review of the documented effects of air pollutants and other stress inducers, on the internal chemistry of conifers, with specific reference to the type of chemicals for which changes are noted, has been initiated.

Report: Further information will be available from the Canadian Forestry Service, Victoria.

8. JOINTLY MANAGED ACTIVITIES

8.1 EMISSIONS AND CONTROL TECHNOLOGY

Inventory of Air Pollution in British Columbia Point Sources Under Waste Management Permit

An inventory of emissions for 1985 for all permitted sources in the British Columbia outside the Greater Vancouver Regional District (GVRD) is completed. The project was commissioned by the Inventory Management Division of Environment Canada and the Waste Management Branch of British Columbia's Ministry of Environment. The inventory included the following contaminants: particulates, sulphur dioxide, nitrogen oxides, carbon monoxide, hydrocarbons, cadmium, lead, vanadium, and polyaromatic hydrocarbons. In addition, an inventory of emissions from hospital incinerators in the province has also been prepared. As part of this project, a database system has also been developed for the emissions from these point sources.

Report: It is anticipated that various reports on emissions from point sources under Waste Management Permit in 1985 will be prepared in the near future. Similar inventories for subsequent years will also be prepared.

Inventory of Air Emissions in Greater Vancouver Regional District

The Greater Vancouver Regional District, in collaboration with Environment Canada and the British Columbia Ministry of Environment, has completed an inventory of the emissions of sulphur oxides, nitrogen oxides, particulates, carbon monoxide and volatile organic compounds. The inventory includes all sources: "point" sources, "area" sources, and "mobile" sources.

This inventory is maintained on a microcomputer database. Uses of the computerized database include: routine updates, database management to facilitate the administration of permits, data transfer and dispersion modelling.

Report: Reports and computer files are available from the Greater Vancouver Regional District, Pollution Control Section.

Inventory of Volatile Organic Compounds (VOC) From Fuel Marketing in Greater Vancouver Regional District

Environment Canada, in cooperation with the Greater Vancouver Regional District (GVRD) and the Ministry of Environment, and the petroleum industry, commissioned a study on the emissions of Volatile Organic Compounds (VOC) from fuel marketing activities in the GVRD area. The first phase of the study consisting mainly of the development of a database system is complete. And, the second phase involving the preparation of an inventory of VOC emissions for the year (1985) is presently being conducted under private contract.

Report: A report will be available when the study is completed.

Emission Inventory Database Task Force

A Task Force has been established representing Environment Canada, the Ministry of Environment, and the Greater Vancouver Regional District (GVRD), to examine the possibility of exchanging computerized emission inventory data.

Report: No report on these activities is planned at the moment.

Photochemical Modelling in Greater Vancouver Regional District

A working group of technical personnel from the Greater Vancouver Regional District (GVRD) and the Ministry of Environment has been set up to coordinate photochemical modelling activities for the Lower Mainland of British Columbia.

Environment Canada, in cooperation with the province and the GVRD, has initiated a pilot project to develop a computerized database to facilitate the exchange of data among the three agencies.

Report: No report is planned, however, details of the project can be obtained through any of the agencies involved.

The Role and Importance of Particulate Emissions in Precipitation Chemistry and Deposition in Western and Northern Canada

Relationships between acid-forming compounds and pH are reasonably well defined in eastern Canada. In western Canada, recent studies have shown that there is essentially no correlation between the hydrogen and sulphate and nitrate ions in precipitation chemistry. It is hypothesized that alkaline particulate matter, as well as particulate sulphates and nitrates, from wind blown

soil may be important in characterizing the chemistry of precipitation and deposition in western and northern Canada.

A program jointly funded by the Governments of Alberta, British Columbia, the Northwest Territories, and Canada will evaluate the role and importance of particulate matter in acidic deposition. The study, comprised of a "data and problem analysis", will lead to an understanding of the impact of particulate emissions on acidic deposition in western and northern Canada.

Concomitant with these investigations, Environment Canada will host a workshop to bring together experts in this field to provide a review and update on current research activities. One major objective of these deliberations and investigations will be to identify future research and monitoring programs for western and northern Canada.

Report: Further information on this program is available from Alberta Environment and the Atmospheric Environment Service, Edmonton.

8.2 AIR QUALITY AND DEPOSITION

Target Loadings for Acidic Deposition in Western Canada

Target loadings can be thought of as a maximum permissible amount of acidic deposition in a specified location, annually. The applicability of this concept for western Canada has been examined in detail since 1985. The main task has been to summarize the available information in a form that is useful to regulatory agencies. Provinces and Territories require this information to develop their own control programs based on the unique regional patterns of emission and environmental sensitivity in their jurisdictions. The background work on the target loading concept was done under contract to the National Research Council by ESSA Environmental and Social Systems Analysts Ltd., and Concord Scientific Corporation. The contractors completed a draft of the final report in 1986. The final report was published by the LRTAP Technical Committee. A task force has been established to develop interim target loadings based on the report recommendations.

Report: The final report **Interim Target Loadings for Acidic Deposition in Western Canada: A Synthesis of Existing Information** is available for distribution from the members of the Technical Committee listed at the beginning of this Annual Report.

8.3 SURFACE WATERS

Lake Sensitivity Mapping for Western and Northern Canada

Lake sensitivity maps have been prepared for each of the western provinces and the Northwest Territories. The map scale is 1:7,500,000. An accompanying report has been prepared describing background to the project, methods used, and general observations on sensitivity.

Report: The overview maps and a report is available from the Technical Committee members listed at the beginning of the Annual Report.

Cree Lake LRTAP Monitoring Study

Water Quality Branch, Environment Canada, and Saskatchewan Environment and Public Safety began a study in 1986 on five small lakes in Cree Lake area of Saskatchewan to: (1) assess the spatial variability within the lake cluster; (2) determine the seasonal patterns including the effect of snowmelt on lake chemistry; (3) assess the effectiveness of Saskatchewan Environment and Public Safety's monitoring program with respect to the best time to collect samples; and (4) conduct biological surveys of the lakes in support of the chemical program and provide baseline information. Water quality sampling during 1987 completed a full year of data collection but resource constraints prohibited the project's continuation. It is presently being re-evaluated.

Report: Further information is available from the Water Quality Branch, Western and Northern Region, Environment Canada, Regina; and, Saskatchewan Environment and Public Safety.

8.4 SOILS AND GEOLOGY

Sensitivity of Western and Northern Canada Soils and Geology to Acidic Inputs

Two small scale (1:7,500,000) coloured maps have been compiled from individual maps prepared for the western provinces, Yukon Territory, and the Northwest Territories. These maps are: **Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition;** and, **Soil Sensitivity to Acidic Inputs.** Relative reliability of input map sources are indicated on the maps. An ac-

companying report describes background to the project, methods used, and general observations on sensitivity.

Report: The following report is available from members of the Technical Committee listed at the beginning of this Annual Report: **Sensitivity of Western and Northern Canada Soils and Geology to Acidic Inputs.** Also available is a report describing mapping methods and rating criteria entitled: **Soils and Geology Sensitivity Mapping in Western Canada – Report of June 27, 28 Meeting, Victoria, British Columbia.**

Environments Sensitive to Acidic Deposition

Combined maps of soil and geology sensitivity and lake sensitivity were prepared for all four western provinces and the Northwest Territories. The maps were entitled: Sensitive Environments to Acidic Deposition and were prepared by computerized overlays of the input maps which rated Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition, and the input maps showing Lake Alkalinity. Multiple combinations were calculated. British Columbia prepared the full scale (1:2,000,000) and page sized maps by digitizing input maps, overlaying, and printing them using their computer system. Location referenced base maps and additional clear film overlays of Soil Sensitivity to Acidic Inputs maps were also prepared to further assist analyses. These combined maps were prepared to aid development of acidic deposition target loadings for western and northern Canada.

Report: Large format maps (1:2,000,000) and page sized maps were prepared in single copy. Thus, the maps have not been published for distribution. However, members of the Technical Committee listed at the beginning of this report may be contacted for information on availability of these reference copies.

8.5 VEGETATION

No activities were conducted in this area.

8.6 HEALTH

Long-Range Transport of Air Pollutants Health Effects

An epidemiological study between Health and Welfare Canada and Saskatchewan Environment and Public Safety is being conducted on elementary school-aged children to assess the potential risk to human health from the long-range transport of air pollutants. The study has been extended to the end of March 1988 to gather further data.

Five communities have been selected in Ontario in an area affected by the long-range transport of air pollutants. Five communities have also been selected in Saskatchewan, an area that is not affected by the long-range transport of air pollutants. The risk to human health will be determined by comparing the data collected from the two areas. The study includes ambient air monitoring of sulphur dioxide, ozone, nitrogen dioxide, carbon monoxide, suspended particulates, and inhalable particulates in each area.

Report: Further information is available from National Health and Welfare Canada.

9. INDUSTRY AND INSTITUTION ACTIVITIES

9.1 BRITISH COLUMBIA

Environmental Biology

Workshops, Literature Reviews, Modelling Effects of Acid Deposition

There were numerous activities of general interest to practitioners in the field of acidic deposition. Among these were: 1) impact assessment of acidic deposition in Canada based on regional lake surveys, intensive watershed studies, and analysis of regional modelling; 2) predictions of frequency and magnitude of acid runoff from snowmelt and rainstorm events; 3) effects of acidic deposition on waterfowl in eastern Canada; 4) refinements of a regional model of the effects of acidic deposition on aquatic resources; 5) mechanisms for episodic acidification of lakes and streams caused by storm and snowmelt events; 6) protocol for the classification of lakes based on the pathways of acidification and sources of acidification (including acidic deposition); 7) development of field research plans for quantifying the chemical and biological effects of acidic episodes; 8) biological indicators of acidification in aquatic ecosystems, to give early warnings of harmful changes (or early indications of improved conditions); and 9) predicting the effects of acidic episodes on fish populations.

Report: Reports of these activities are available from ESSA Environmental and Social Systems Analysts Ltd., Box 12155 – Nelson Square, No. 705 - 808 Nelson Street, Vancouver, British Columbia, V6Z 2H2.

Biomonitoring for Effects of Ozone Pollution on Agricultural Production in the Lower Mainland of British Columbia

A network of biomonitoring sites was established throughout the Lower Mainland during the growing seasons of 1985, 1986 and 1987. Tobacco Bel-W_3 was the indicator plant used, due to its high sensitivity to atmospheric ozone and resultant distinctive leaf injury. Research has demonstrated that a correlation exists between the extent of leaf injury and atmospheric ozone levels.

Seven biomonitor sites were established in 1985, while twelve sites were established in 1986 and 1987. Four plants were grown in each station, which provided standardized growing conditions (soil, nutrients, water) to the extent possible.

Spatial and temporal variations in leaf injury due to ozone were observed in all three growing seasons, but overall leaf injury was much greater in 1985. Relatively little injury was observed in 1986 and 1987. Examination of the atmospheric ozone trends from the government-operated ambient air pollution monitoring network confirmed that average ozone levels were considerably higher in 1985 than in 1986 or 1987. Based on the data obtained, it may be concluded that Bel-W_3 can be used to indicate the presence of potentially harmful levels of ozone, but it cannot reliably indicate the ozone concentration. The research is additionally attempting to establish a quantitative relationship between Bel-W_3, injury, and yield reductions of agricultural crops due to ozone. This experiment is being conducted at the UBC Plant Science Field Laboratory, and involves addition of ozone, in proportion to the existing ambient ozone level, to field plots containing potato, pea, and Bel-W_3.

In the summer of 1986 and 1987, a computer-controlled Zonal Air Pollution System (ZAPS) was used to deliver ozone to the treatment plots through manifolds suspended above the plants. In 1986, extensive leaf injury to Bel-W_3 was observed, and correlated with significant crop yield reductions. The overall ozone distribution was lower in 1987, with the result that leaf injury to Bel-W_3 was minimal. However, small but significant yield reductions did occur. These are encouraging initial results for the use of tabacco Bel-W_3, as a biological indicator of potential harmful effects to crops. Future research will attempt to 'fine-tune' this relationship.

This research is being conducted by Gordon Brown, PhD Candidate, Resource Management Science, University of British Columbia, under the direction of Dr. Vic Runeckles, Department of Plant Science. Funding was provided by Agriculture Canada.

Report: Not yet available.

Use of Expert Judgments to Predict the Risk of Agricultural Crop Damage from Ozone Pollution in the Lower Mainland of British Columbia

Determining the risk of ozone pollution damage to agriculture requires knowledge about pollution levels as well as dose-response relationships.

Air quality information is available for the Lower Mainland of British Columbia through an exten-

sive government-operated air monitoring network. Unfortunately however, our knowledge of dose-response relationships for ozone effects on crops in the Lower Mainland is minimal. Sufficient scientific knowledge will only become available through experiments with local crops and cultivars, under local growing conditions. This is an expensive process, and would require several growing seasons of data before accurate predictions about impacts on yield could be made.

Direct use of dose-response models developed elsewhere (e.g., U.S. National Crop Loss Assessment Network) is inappropriate due to genetic differences in crops as well as differences in local growing conditions. Under these circumstances, expert judgments of the risks of ozone damage to crops may be useful. If there is a problem (if agricultural yields are being affected), it would be desirable to be able to judge the risk, and potential impact, as soon as possible.

Expert judgments have been used elsewhere in air pollution policy analysis, but a systematic means for selecting experts, and for evaluating 'expertise', has not been developed. Since scientific experts often disagree on subjects involving uncertainty, more weight is frequently given to judgments from scientists who are perceived to have 'more expertise'. The present research involves defining the dimensions of expertise, selecting experts, eliciting judgments of risks to crops in the Lower Mainland and weighing of judgments according to relative 'expertise', in the development of a crop risk assessment model.

This research is being conducted by Gordon Brown, PhD Candidate, Resource Management Science, under the direction of Dr. Ilan Vertinsky, Institute of Resource Ecology.

Report: Not yet available.

9.2 ALBERTA

Lindbergh Environmental Study

The study was designed to determine the existing and potential quality of the Lindbergh/Elk Point region airshed in conjunction with heavy oil development. The study was designed and will be implemented in four phases, including a review of existing air quality data, determination of baseline regional air quality, characterization of potential emission sources from development, and prediction of regional air quality by model development. The study was initiated in 1984, and the last phase was completed in 1987.

The study provided three major results: (1) a detailed chemical composition of industrial gaseous emissions; (2) an assessment of regional air quality indicated that no impact on air quality is expected from H_2S, SO_2, or NO_X emissions for low, medium, and high development scenarios (i.e., all forecasts of maximum ground level concentrations were below provincial standards); and (3) odours originated from total reduced sulphur and non-methane hydrocarbons, not H_2S emissions.

Report: Reports on the emission characterization and regional air quality impact assessment are available from Amoco Canada.

Supplementary Emission Control

The objective of this work is to develop the capability to predict and control ambient sulphur dioxide concentrations in the vicinity of the Suncor Oil Sands Plant. This will be accomplished through data collection, model development and testing, control technology development, and real time air quality data processing. The technical feasibility component of this work has been completed.

Report: For further information,
contact Mr. Letkeman,
Environmental Affairs,
Suncor, P.O. Box 4001,
Fort McMurray, Alberta,
T9H 3E3.

Forest Biomonitoring in the Vicinity of the Suncor Oil Sands Plant

The objective of the study is to measure the extent of the impact of industrial emission on the forests within an 11 km radius of the Suncor Oil Sands Plant. Work included annual assessments of the health of forest growth since 1976, including natural and industrial effects on trees. Soil pH sampling, growth rate analysis, and forest litter studies were conducted. In 1987, a lichen field study and literature survey were completed. Results so far show no detrimental effects to trees, shrubs and soils from industrial emissions.

Report: For further information,
contact Mr. Letkeman,
Environmental Affairs,
Suncor, P.O. Box 4001,
Fort McMurray, Alberta,
T9H 3E3.

Alberta Government and Industry Acid Deposition Research Program

The government-industry acid deposition research program (ADRP) is a multi-million dollar pro-

gram beginning its fifth year in 1987. The agencies involved in this program include the Alberta Government, the Canadian Petroleum Association, Alberta's electrical utilities, and the Energy Resources Conservation Board. The program's overall objective is to assess the environmental impact of acid-forming gases in Alberta. Current work includes two individual projects:

1. a 42-month Biophysical Research Program, Critical point I, to be completed in the fall of 1988;
2. a feasibility study into occupational health for gas and thermal plant workers.

In 1986, the project on administration and management of the Southwest Alberta Medical Diagnostic Review was completed. Biophysical world literature reviews and emissions inventory of sulphur oxides and nitrogen oxides reports were released.

Report: All published reports are available from the ADRP office.

Assessment of Effects of Acidic and Acid Forming Substances on Alberta Soils

The objective of the project is to predict if and when in the future adverse effects on soils in Alberta due to acidic and acidifying substances. The soils component of this research is being carried out through application of a model which predicts changes in soil chemical properties resulting from acid deposition.

Report: A final report is to be submitted to the sponsor (ADRP) by April 15, 1988.

9.3 SASKATCHEWAN

Saskatchewan Power Corporation Monitoring Activities at Poplar River (Coronach) and Boundary Dam (Estevan) Power Stations

One station continuously monitoring ground level concentrations of sulphur dioxide is located at the Canada/U.S. International Boundary south of the Poplar River Power Station. Emissions at the Poplar River Power Station are continuously monitored for opacity, sulphur dioxide, and nitrogen oxides concentrations. Surface waters in the vicinity of the Poplar River, Boundary Dam, Queen Elizabeth, and Estevan power stations are monitored and analyzed for pH, sulphates, nitrates, alkalinity, etcetera.

Report: Further information is available from the Saskatchewan Power Corporation and Saskatchewan Environment and Public Safety.

Saskatchewan Power Corporation Agricultural Monitoring Program – Poplar River Power Plant, 1987

As part of this program, the Saskatchewan Research Council measured sulphation levels at thirty-two sites. Rainfall samples at five sites were collected and analyzed for pH, sulphate, nitrate, calcium, magnesium, potassium, sodium, chloride and specific conductance. Soil chemistry was monitored for pH and sulphur content and wheat crops were analyzed for chlorophyll-a, chlorophyll-b, nitrogen and sulphur.

Report: Further information is available from the Saskatchewan Power Corporation.

Saskatchewan Power Corporation – SO_2/NO_X Emission Reduction Program

The final report for the Demonstration SO_2/NO_X Reduction Program carried out on Boundary Dam Power Station Unit 4 was approved in early 1987 by the co-funding project monitors.

In 1987, a series of tests were completed on the economizer injection location. Testing was also performed on four different hydrates in an attempt to identify the most efficient sorbents to be used in the future. The variation included calcitic/dolomitic materials and pressure/atmospheric manufacturing processes. No reports are available on these aspects of the test work.

Additional testing is anticipated in order to investigate upper furnace injection of limestone and back-end humidification.

Report: Reports and information are available from the Director, Materials Research, Research and Development Centre, Saskatchewan Power Corporation.

Saskatchewan Power Corporation – Development of Improved Reagents for SO_2 Capture in Dry Injection Systems

Laboratory tests and experimentation are continued on development of improved calcium-based reagents for abatement of sulphur dioxide emissions. Potentially cost-effective methods of achieving finer calcium hydroxide sorbents have been identified in the work done in 1987. Whether these improvements in sorbent particulate size translate into greater reactivity to SO_2 will be determined in work planned for 1988.

Report: Information available from Director, Materials Research, Research and Development Centre, Saskatchewan Power Corporation.

Monitoring at Amok Ltd. Uranium Mine, Cluff Lake

The average sulphation levels are determined on a monthly basis at 23 sites around the mine using lead peroxide plates.

Report: Data summaries are available from Amok Ltd. and Saskatchewan Environment and Public Safety.

Monitoring at Eldor Mines Uranium Mine, Rabbit Lake

Eldor Mines continuously monitors ground level concentrations of sulphur dioxide at one site.

Report: Data summaries are available from Eldor Mines and Saskatchewan Environment and Public Safety.

Comparative Injury to Saskatchewan Vegetation Caused by Acidic Precipitation

The objectives of this research are: (1) To compare the sensitivities of plant tissues to acidification, primarily by use of the membrane leakage test, and (2) To investigate the mode of injury from excess acidity, including the direct effects of hydrogen ions, and the synergistic effects of other ions. Comparisons are being made on several important boreal species, including trees, shrubs and herbs. The study will be completed in 1989.

Report: Further information is available from R. E. Redmann, Department of Crop Science and Plant Ecology, University of Saskatchewan.

9.4 MANITOBA

Monitoring in Thompson

A permanent station continuously monitoring ground level concentrations of sulphur dioxide is northwest of the Inco non-ferrous smelter facility located between the plant and the Town of Thompson. A mobile station is used during the spring, summer, and early fall (during the growing season) to monitor sulphur dioxide concentrations from other directions. A telemetry system has recently been installed which improves the ability to obtain data.

In addition to measuring ground level concentrations of sulphur dioxide, there is a meteorological program to regulate the smelter production so that acceptable concentrations of sulphur dioxide are maintained under differing dispersion conditions.

Satellite imagery is being used to detect and map vegetation changes in the Thompson area. Maps have been prepared for 1973, 1978 and 1983.

Report: Data summaries are available from Inco Limited.

Removal of Sulphur – Inco

A research program is being conducted by Inco Ltd., Manitoba Division, on the reduction of sulphur in the concentrate being smelted. The program, which is sponsored under the Canada/Manitoba Mineral Resources Development Agreement, is investigating techniques for increased economical removal of high sulphur pyrrhotite in the mill with minimization of metal losses in the smelting process.

Report: This is an ongoing program. Further information is available through Inco Limited.

Monitoring in Flin Flon

Three stations continuously monitor ground level concentrations of sulphur dioxide within 5.0 kilometres (km) of the 250 metre high main stack of the non-ferrous smelter facility.

Report: Data summaries are available through Hudson Bay Mining and Smelting Company Ltd.

Removal of Sulphur – Hudson Bay Mining and Smelting

Several studies to research and develop process technology have been done, or are currently underway, to reduce emissions from the zinc and copper producing operations of Hudson Bay Mining and Smelting Company at Flin Flon.

Report: These are ongoing programs. Further information is available through Hudson Bay Mining and Smelting Company Ltd.

10. ANNUAL DEPOSITION OF WET SULPHATE AT SAMPLING STATIONS IN WESTERN CANADA

SULPHATE DEPOSITION TABLES

Calculation of Deposition at CANSAP Stations

Depositions from CAPMON stations are from data published in CAPMON **Precipitation Chemistry Data Summaries 1983-1986,** published by the Atmospheric Environment Service, Downsview, Ontario. Deposition data from the CANSAP stations have not been published but were calculated from available concentration data. Depositions were calculated for the last three years for which data are available and during which the CANSAP protocol was unchanged. Years for which fewer than ten months of data were available were omitted. For years with ten or more months of data, depositions were calculated using the standing gauge precipitation-weighted concentration and total annual precipitation.

The CANSAP data are included since they are the best available for the period.

Key to Symbols

– no data, or insufficient data, or data not yet available.

1. CANSAP station
2. CAPMON station
3. Provincial station

( )values in parentheses have been corrected for sea salt

e estimated value

* annual deposition based on eleven months of data. Data for November seemed to be erroneously high and were excluded from the set.

Table 1. Annual Deposition of Wet Sulphate at Sampling Stations in British Columbia

STATION	Annual Deposition of Wet Sulphate ($SO_4^=$) kilograms per hectare					
YEAR	1982	1983	1984	1985	1986	1987
Agassiz	–	–	–	11.4	12.5e	–
				(10.4)	(11.2)e	
Cranbrook	–	–	–	–	5.9	4.3
Dawson Creek	–	–	–	–	–	–
Fort Nelson (1)	6.3	4.4	5.0	4.0	–	–
Fort St. John (1)	6.0	6.0	5.8	4.4	–	–
Kamloops	–	–	–	–	2.0	1.18
Kelowna (1)	3.4	3.0	–	3.1	–	1.45
					13.7e	
Kitimat	–	–	12.0	–	(12.4)e	16.95
Nanoose	–	–	–	7.9	7.4e	7.10
				(6.2)	(5.9)e	
Pender Island	–	–	–	5.8	7.1e	
				(4.4)	(5.7)e	
Port Hardy (1)	15.1	15.8	19.4*	–	–	11.63
	(8.0)	(9.5)	(14.3)*			
Prince George (1)	16.4	8.7	5.7	7.9	–	
Revelstoke (1)	6.1	5.8	6.1	4.4	–	
Sechelt	–	–	–	7.9	8.0e	
Semour Dam	–	–	–	–	–	32.4
Smithers	–	–	2.3	–	1.7	1.69
Spectacle Lake	–	–	–	4.7	4.9	12.27
				(3.5)e		
Squamish	–	–	–	17.7	18.7e	26.09
				(16.4)	(16.4)e	
Terrace (1)	4.5	4.4	8.3	10.1	–	
	(4.2)	(4.1)	(7.9)	(9.6)		
Vancouver (1)	22.2	22.4	–	16.4	–	12.80
	(19.9)	(20.4)		(14.9)		
Victoria	–	–	18.7	10.9	20.3e	19.63
				(8.4)	(17.1)e	

Table 2. Annual Deposition of Wet Sulphate at Sampling Stations in Alberta[1]

STATION	Annual Deposition of Wet Sulphate (SO_4^{2-}) kilograms per hectare				
YEAR	1983	1984	1985	1986	1987
Beaverlodge	6.3	5.3	3.6	3.7	3.7
Calgary	8.4	7.4	6.4	6.8	5.6
Cornation [4]	4.9 (5.8)	5.9	9.8	–	–
Edmonton	5.9	11.0	6.6	8.2	5.3
Edson [4]	6.4 (7.8)	10.1	7.5	–	–
Fort McMurray [4]	6.8 (7.1)	9.6 (10.8)	8.9	–	14.4
Lethbridge [4]	4.7 (7.7)	6.5	5.2	–	–
Red Deer	5.9	7.7	5.6	8.0	5.2
Rocky Mountain House [4]	6.5 (9.3)	7.2 (12.6)	6.6	–	–
Suffield	4.7	4.2	12.8	10.2	4.6
Whitecourt	9.9	16.9	21.4	13.5	8.1
Cold Lake	–	–	3.4	2.5	3.1
High Level	–	–	4.6	3.9	3.6[5]
Kananaskis	–	–	7.2	6.1	5.7

[1] In parenthesis are the values reported by CANSAP[1] which uses different criteria and rules for calculations.

[4] CANSAP stations which were terminated in February 1986.

[5] June data were invalidated and excluded from computation.

Table 3. Annual Deposition of Wet Sulphate at Sampling Stations in Saskatchewan

STATION	Annual Deposition of Wet Sulphate ($SO_4^=$) kilograms per hectare					
YEAR	1982	1983	1984	1985	1986	1987
Cluff Lake (3)	2.1	1.8	3.9	2.0	1.9	–
Cree Lake (1)	3.9	–	–	–	–	–
Cree Lake (2)	–	–	4.3	2.9	2.4	–
Cree Lake (3)				2.6	2.0	–
Dreaver Lake (3)	2.0	2.6	2.3	2.8	2.2	–
Kane Lake (3)	2.6	2.0	3.2	3.6	2.6	–
Kindersley (1)	15.4	–	–	–	–	–
Lloyd Lake (3)	–	3.2	–	1.9	1.1	–
Stoney Rapids (3)	0.9	0.8	1.7	–	1.0	–
Wynyard (1)	9.2	10.2	–	–	–	–
Pelican Narrows (3)	–	–	–	2.1	3.3	–

Table 4. Annual Deposition of Wet Sulphate at Sampling Stations in Manitoba

STATION	Annual Deposition of Wet Sulphate ($SO_4^=$) kilograms per hectare					
YEAR	1982	1983	1984	1985	1986	1987
Bissett (1)	7.9	–	–	–	–	–
Brochet (3)	–	–	6.0	2.8	3.4	3.2
Dauphin (1)	13.3	–	–	–	–	–
Gillam (3)	–	–	5.8	3.9	3.4	3.3
Island Lake (2)	–	–	4.8	3.0	3.1	–
Island Lake (3)	8.7	7.7	4.9	3.7	3.3	4.7
McCreary (2)	–	–	6.3	3.5	3.4	–
Norway House (3)	7.2	8.2	6.0	4.1	4.2	3.6
Pointe du Bois (3)	–	–	5.6	9.1	4.5	3.8
The Pas (1)	7.3	–	–	–	–	–
Winnipeg (3)	–	–	–	–	5.4	5.9

Table 5. Annual Deposition of Wet Sulphate at Sampling Stations in the Northwest Territories and in the Yukon

STATION	Annual Deposition of Wet Sulphate ($SO_4^=$) kilograms per hectare				
YEAR	1982	1983	1984	1985	1986
NORTHWEST TERRITORIES					
Fort Reliance (1)	2.6	–	–	–	–
Hay River (1)	3.4	5.8	–	7.8	–
Inuvik (1)	5.0	–	–	–	–
Mould Bay (1)	4.9	–	–	–	–
YUKON TERRITORIES					
Whitehorse	3.1	2.7	2.1	1.4	–

11. ADDRESSES FOR FURTHER INFORMATION

BRITISH COLUMBIA

Ministry of Environment and Parks
Parliament Buildings
Victoria, British Columbia
V8V 1X5

ESSA Environmental and Social
Systems Analysts
#705 - 808 Nelson Street
Vancouver, British Columbia
V6Z 2H2

Institute of Animal Resource Ecology
2204 Main Mall
University of British Columbia
Vancouver, British Columbia
V6T 1W5

ALBERTA

Acid Deposition Research Program
1500 - 633 Sixth Avenue S.W.
Calgary, Alberta
T2P 2Y5

Alberta Environment
Pollution Control Division
6th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, Alberta
T5K 2J6

Alberta Environment
Corporate and Strategic
Management Division
14th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, Alberta
T5K 2J6

Alberta Environment
Technical Development Branch
Earth Sciences Division
P.O. Box 3014
Cousins Building
Lethbridge, Alberta
T1J 4B3

Alberta Environmental Centre
Environmental Chemistry Wing
Bag 4000
Vegreville, Alberta
T0B 4L0

MANITOBA

Hudson Bay Mining and Smelting Company Ltd.
Supervisor Environmental Control
Flin Flon, Manitoba
R8A 1N9

Inco Ltd.
Director
Safety, Health and Environment
Manitoba Division
Thompson, Manitoba
R8N 1P3

Manitoba Environment and
Workplace Safety and Health
Environmental Standards and
Studies
Box 7, Building 2
139 Tuxedo Avenue
Winnipeg, Manitoba
R3N 0H6

NORTHWEST TERRITORIES

Pollution Control Division
Renewable Resources
Government of the Northwest Territories
P.O. Box 1320
Yellowknife, Northwest Territories
X1A 2L9

Wildlife Service
Renewable Resources
Government of the Northwest Territories
P.O. Box 1320
Yellowknife, Northwest Territories
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SASKATCHEWAN

Amok Ltd.
817, 825 - 45th Street West
P.O. Box 9204
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Department of Crop Science and
Plant Ecology
University of Saskatchewan
Saskatoon, Saskatchewan
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Eldor Mines
P.O. Box 2070
Saskatoon, Saskatchewan
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Saskatchewan Environment and
Public Safety
Walter Scott Building
3085 Albert Street
Regina, Saskatchewan
S4S 0B1

Institute of Pedology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

Saskatchewan Power Corporation
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

Saskatchewan Research Council
15 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 2X8

FEDERAL AGENCIES

ALBERTA (Federal)

Canadian Wildlife Service
Environment Canada
2nd Floor
4999 - 98th Avenue
Edmonton, Alberta
T6B 2X3

Environmental Protection
Western and Northern Region
Conservation and Protection
Environment Canada
2nd Floor, Twin Atria #2
4999 - 98th Avenue
Edmonton, Alberta
T6B 2X3

Northern Forestry Centre
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Scientific Services Division
Western Region
Atmospheric Environment Service
2nd Floor, Twin Atria Building
4999 - 98th Avenue
Edmonton, Alberta
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BRITISH COLUMBIA (Federal)

Environmental Protection
Pacific and Yukon Region
Conservation and Protection
Environment Canada
3rd Floor, Kapilano 100
Park Royal
West Vancouver, British Columbia
V7T 1A2

Fisheries and Oceans Canada
Fisheries – Pacific Region
1090 West Pender Street
Vancouver, British Columbia
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Scientific Service Division
Pacific Region
Atmospheric Environment Service
700 - 1200 West 73rd Avenue
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Institute of Ocean Sciences
9860 West Saanich Road
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Pacific Forestry Centre
Canadian Forestry Service
506 West Burnside Road
Victoria, British Columbia
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MANITOBA (Federal)

Freshwater Institute
Department of Fisheries and Oceans
501 University Crescent
Winnipeg, Manitoba
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Scientific Services Division
Central Region
Atmospheric Environment Service
266 Graham Avenue
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NORTHWEST TERRITORIES (Federal)

Inland Waters/Lands
Environment Canada
Box 2970
Yellowknife, NWT
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ONTARIO (Federal)

Atmospheric Research Directorate
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

Health and Welfare Canada
Brooke Claxton Building
Ottawa, Ontario
K1A 0K9

LRTAP Liaison Office
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

SASKATCHEWAN (Federal)

Inland Waters/Land
Western and Northern Region
Conservation and Protection
1st Floor, Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 3R4

Scientific Services Division
Central Region
Atmospheric Environment Service
Airport Terminal Building
Box 4800
Regina, Saskatchewan
S4P 3Y4

12. GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ADRP – **A**cid **D**eposition **R**esearch **P**rogramme (Alberta)

AES – **A**tmospheric **E**nvironment **S**ervice

ARNEWS – **A**cid **R**ain **N**ational **E**arly **W**arning **S**ystem

CANSAP – **C**anadian **N**etwork for **S**ampling **P**recipitation

CAPMON – **C**anadian **A**ir and **P**recipitation **M**onitoring **N**etwork

EPA – **E**nvironmental **P**rotection **A**gency (U.S.)

EPRI – **E**lectric **P**ower **R**esearch **I**nstitute

kg/ha/yr – kilograms per hectare per year

LRTAP – **L**ong **R**ange **T**ransport of **A**ir **P**ollutants

PNWIS-APCA – **P**acific **N**orthwest **I**nternational **S**ection – **A**ir **P**ollution **C**ontrol **A**ssociation

RMCC – **R**esearch and **M**onitoring **C**o-ordinating **C**ommittee

SO_2 – Sulphur dioxide

NO_x – Nitrous oxides

ZAPS – **Z**onal **A**ir **P**ollution **S**ystem

13. PRIORITIES FOR CO-ORDINATED RESEARCH AND MONITORING (1985-1988)

In September 1985 the governments of British Columbia, Alberta, Saskatchewan, Manitoba, the Northwest Territories, and Canada signed a second three-year Western and Northern Canada Acid Deposition/LRTAP agreement. The new agreement covers the period 1985 to 1988, and addresses the following eight priorities:

1. Deposition monitoring (including snowpack surveys)

This program was implemented during the initial three years of co-ordinated effort, and will continue together with the regular update of emissions inventories. This information will serve as an indicator of any deteriorating changes.

2. Deposition criteria for Western and Northern Canada

It is apparent that the target loading of 20 kilograms per hectare per year (kg/ha/yr) of wet sulphate used in eastern Canada may not be appropriate for western and northern Canada. In eastern Canada deposition rates are above 20 kg/ha/yr at many receptor points and several sensitive ecosystems already show signs of deterioration. The target loading of 20 kg/ha/yr is intended to protect at least the moderately sensitive aquatic ecosystems are not damaged yet and the deposition rates are generally below 20 kg/ha/yr. The relative importance of dry deposition and total acid loading criteria are of concern; therefore, target loadings for western Canada should be developed.

3. Medium-Range Transport Deposition Model

The Atmospheric Environment Service trajectory and deposition model, which has been applied in western Canada, did not provide sufficient information for making management decisions. A medium-range model on a smaller grid scale is required to better characterize the situation. The long-range transport of air pollutants is less critical in western and northern Canada than in eastern Canada, and receptor points are mainly affected by local sources.

4. Background Sulphate ion Concentrations and the Role of Dust

The precipitation chemistry over western and northern Canada is different from that over eastern Canada. The difference in climate is a factor, and the role played by dust may be important in characterizing the precipitation chemistry. It is expected that these studies will assist in evaluating the respective contributions to acid depositions from man-made sources, as well as local and background sources.

5. Role of Dry Deposition

The amount of dry deposition relative to total deposition is not known for western and northern Canada. This will be studied to assist in determining deposition criteria. Monitoring programs and modelling studies will be developed.

6. Monitoring Surface Water and Terrestrial Environmental Quality

This program is an extension of the one that began in the initial 1982 to 1985 period. The information is needed to fill in gaps in the assessment of potential sensitivity to acid deposition. Identification of long-term trends is important.

7. Impacts in Highly Sensitive Zones

Field studies will be carried out to investigate the impacts on aquatic and terrestrial ecosystems in areas where sulphate loadings are high and in sensitive areas identified through the sensitivity mapping carried out over the past three years.

8. Control Technology Research Methods and Strategy Options

The technology to control emissions is being reviewed by the Environmental Protection Service. This task will be continued with the aim of assessing the applicability of new control technologies to western and northern Canada. Strategy models that provide control options are currently in existence (e.g. the Ontario Model). These will be assessed in terms of their applicability to western and northern Canada.

Each agency has undertaken projects to address these priorities. Annual reports and copies of the 1985 to 1988 research and monitoring program are available from the participating agencies.